



January 27, 2016

## FOUNDATION INVESTIGATION REPORT

### Culvert Extension, Twinning and Replacement Highway 400 from Essa Road to Dunlop Street West, Barrie, Ontario G.W.P. 2159-11-00

**Submitted to:**

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**GEOCRES No. 31D-634**

**Report Number: 1532543-3**

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REPORT





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## FOUNDATION REPORT - CULVERT EXTENSION, TWINNING AND REPLACEMENT, G.W.P. 2159-11-00

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### **APPENDIX C    Record of Boreholes from Previous Investigation (GEOCRE No. 31D-589)**

Records of Boreholes C1 to C5, RW12



## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the culvert extension, twinning and replacement of two culverts near the Highway 400/Tiffin Road interchange, in Barrie, Ontario. This report addresses the foundation investigation completed for the proposed culvert extension, twinning and replacement.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert locations, by means of a limited borehole investigation and geotechnical laboratory testing on selected samples.

Golder has completed the foundation engineering services in general accordance with the scope of work provided in Proposal No. GEOTETOB22161AA, dated March 13, 2015, originally provided to MH by Coffey Geotechnics Inc. (Coffey).

## **2.0 SITE DESCRIPTION**

### **2.1 Culvert at Station 29+280**

The culvert to be extended/twinning is located approximately 250 m south of the Barrie Collingwood Railway Overpass along Highway 400 in the City of Barrie at approximately Station 29+280 as shown on the Key Plan on Drawing 1. The existing culvert is a 1800 mm diameter, 70 m long CSP, with the invert at Elevation 230.0 m. The existing Highway 400 grade at the site is at approximately Elevation 238.5 m.

### **2.2 Culvert at Station 10+120**

The culvert to be replaced is located approximately 100 m north of the Tiffin Street Overpass structure along Highway 400 in the City of Barrie at approximately Station 10+120 as shown on the Key Plan on Drawing 2. The existing culvert is a Rigid Frame Open Footing (RFOF) concrete structure with a span of 1220 mm, a rise of 1200 mm and a length of 61 m. The stream bed at the culvert location and is at Elevation 232.0 m. The existing Highway 400 grade at the site is at approximately Elevation 237.8 m.

## **3.0 INVESTIGATION PROCEDURES**

### **3.1 Previous Investigation by Others**

Coffey completed a preliminary foundation investigation for the culvert extension/replacement comprising six boreholes (Boreholes C1 to C5 and RW12) in October 2014. The locations, ground surface elevations and drilled depths of these boreholes are summarized below and the borehole locations are also shown on Drawings 1 and 2.



## FOUNDATION REPORT - CULVERT EXTENSION, TWINNING AND REPLACEMENT, G.W.P. 2159-11-00

Culvert Location	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
Culvert Station 29+280	C1	4,914,237.9	288,578.9	232.0	3.1
	C3	4,914,174.7	288,531.9	233.0	8.2
	C5	4,914,205.6	288,547.5	238.7	14.3
Culvert 2 Station 10+120	C2	4,914,672.0	288,212.1	233.3	8.2
	C4	4,914,647.2	288,140.5	233.7	8.2
	RW12	4,914,649.3	288,175.8	237.7	9.8

The results of the culvert foundation investigation are presented in Coffey's Preliminary Foundation Investigation and Design Report (GEOCREC No. 31D-589) dated February 11, 2015.

### 3.2 Current Investigation

Golder advanced an additional two boreholes adjacent to the two culvert locations: Borehole HF1 was advanced near Culvert Station 29+280; and Borehole TRW-3 was advanced near Culvert Station 10+120. These boreholes were advanced as part of the high fill and retaining wall foundation investigation for the Highway 400 embankment widening adjacent to the culverts. The field work for the subsurface investigation was carried out on June 23 and July 15, 2015, during which time the two boreholes were advanced using a track-mounted drill rig, supplied and operated by Canadian Soil Drilling of Springwater, Ontario.

Boreholes HF1 and TRW-3 were advanced to depths of 10.1 and 12.8 m below existing ground surface using hollow stem auger drilling methods. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586).

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations. All boreholes were backfilled with bentonite upon completion, in accordance with Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by a member of Golder's technical staff who observed the drilling, sampling and in situ testing operations, and logged the subsurface conditions encountered in the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water content determinations and grain size distributions were carried out on selected soil samples.

The borehole locations and ground surface elevations were obtained from the digital terrain model provided by MH. The borehole locations, including MTM NAD83 and UTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and the drilled depths are summarized below and the borehole locations are shown on Drawings 1 and 2.



## FOUNDATION REPORT - CULVERT EXTENSION, TWINNING AND REPLACEMENT, G.W.P. 2159-11-00

Culvert	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
Culvert Station 29+280	HF1	4,914,216.0	288,583.2	233.2	10.1
Culvert Station 10+120	TRW-3	4,914,663.2	288,187.6	237.8	12.8

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

This section of Highway 400 lies within the Simcoe Lowlands, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam)<sup>1</sup>. The soil deposits are typically interlayered non-cohesive, sand and silt deposits, with occasional cohesive clayey silt / silty clay layers.

### 4.2 Subsurface Conditions

Four boreholes (Boreholes HF1, C1, C3 and C5) were advanced near Culvert Station 29+280 and four boreholes (Boreholes TRW-3, C2, C4 and RW12) were advanced near Culvert Station 10+120. The interpreted stratigraphic conditions at the culvert sites are shown on Drawings 1 and 2, respectively.

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced as part of the current investigation and the results of in situ and laboratory testing are given on the borehole records contained in Appendix A. The results of geotechnical laboratory testing are also presented on Figures B1 to B4 contained in Appendix B for the current investigation. The borehole records and laboratory test results from the Coffey Geotechnics Inc. investigation (GEOCREC No. 31D-589) are contained in Appendix C.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profiles and cross-sections on Drawings 1 and 2 are inferred from observations of drilling progress and from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsoils at the culvert sites consist of embankment fill underlain by a deposit of loose to dense sandy silt to silty sand interlayered with a loose to compact silt deposit. Peat was encountered underneath the fill at one borehole location.

A more detailed description of the subsurface conditions encountered in the boreholes at the culvert sites is provided in the following sections.

<sup>1</sup> Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.



#### **4.2.1.1 Asphalt**

An approximately 150 mm thick layer of asphalt was encountered at ground surface in Borehole C5 at Culvert Station 29+280; and an approximately 220 mm and 400 mm thick layer of asphalt was encountered at ground surface in Boreholes TRW-3 and RW12 at Culvert Station 10+120.

#### **4.2.1.2 Topsoil**

An approximately 100 mm and 200 mm thick layer of topsoil was encountered at ground surface in Boreholes C1 and C3 at Culvert Station 29+280; and an approximately 100 mm thick layer of topsoil was encountered at ground surface in Boreholes C2 and C4 at Culvert Station 10+120.

#### **4.2.1.3 Fill**

Fill materials of variable composition and layer thickness was encountered at all borehole locations. The elevations of the surface and base of the fill and the layer thickness of the fill materials as encountered in the boreholes are summarized below.

<b>Culvert Location</b>	<b>Borehole No.</b>	<b>Depth to Surface of Fill (m)</b>	<b>Fill Surface Elevation (m)</b>	<b>Fill Thickness (m)</b>	<b>Base of Fill Elevation (m)</b>
Culvert Station 29+280	HF1	0.0	233.2	3.7	229.5
	C1	0.1	231.9	1.6	230.3
	C3	0.2	232.8	0.4	232.4
	C5	0.2	238.5	5.1	233.4
Culvert Station 10+120	TRW-3	0.4	237.4	3.3	234.1
	C2	0.1	233.2	1.4	231.8
	C4	0.1	233.6	0.6	233.0
	RW12	0.2	237.5	3.5	234.0

The fill materials vary in composition from silt to silt and sand to silty sand trace gravel; and sand to gravelly sand immediately under the asphalt. Cobbles were encountered in the upper 0.7 m of the fill deposit in Borehole HF1. Rootlets or trace organics were encountered in all boreholes to depths of about 3.0 m below ground surface, except Boreholes TRW-3 and RW12. Silty clay lenses were encountered in the fill deposit in Borehole C5.

The Standard Penetration Test (SPT) "N"-values within the non-cohesive fill materials range from 1 to 42 blows per 0.3 m of penetration, indicating a very loose to dense relative density.

The water content of the fill deposit range from about 4 percent to 31 per cent.

The results of grain size distribution tests completed on two selected samples of the fill from the current investigation are shown on Figures B1 and B2 in Appendix B.





#### **4.2.1.4 Peat**

A 1.1 m thick deposit of peat was encountered in Borehole C1 underlying the non-cohesive fill at Elevation 230.3 m. The measured SPT "N"-values within the peat are 1 blow and 5 blows per 0.3 m of penetration, suggesting a very soft to firm consistency.

#### **4.2.1.5 Sandy Silt to Sand**

All of the boreholes encountered and terminated in a variable non-cohesive deposit ranging in composition from sandy silt to silt and sand to silty sand to sand, trace clay, trace gravel. Auger grinding was noted between Elevations 231 m and 230 m (2.7 m to 3.7 m depth) in Borehole C4 on inferred cobbles. Discontinuous silty clay to clayey silt layers or lenses were encountered in Boreholes C2, RW12 and C4 within the non-cohesive deposit.

Most boreholes also penetrated through a silt stratum interlayered with the sandy silt to sand deposit as noted below. The elevations of the surface and base of the sandy silt to sand deposit and the thickness of the deposit as encountered in the boreholes are summarized below.

Culvert Location	Borehole No.	Deposit Surface Depth (m)	Deposit Surface Elevation (m)	Deposit Thickness (m)	Deposit Base Elevation (m)
Culvert Station 29+280	HF1	*3.7	229.5	1.9	227.6
		5.6	227.0	>4.5	Below 223.1
	C1	2.8	229.2	> 0.3	Below 228.9
	C3	0.6	232.4	> 7.6	225.5
		*3.1/7.5	229.9/225/5	3.5/0.7	226.4/Below 224.8
	C5	5.3	233.4	3.2	230.2
		*8.5	230.2	>5.8	Below 224.4
Culvert Station 10+120	TRW-3	3.7	234.1	7.6	Below 224.9
		*10.2	227.5	1.5	226.1
	C2	1.5	231.8	3.2	Below 225.1
		*3.7	229.6	3.5	226.1
	C4	0.7	233.0	> 7.5	Below 225.5
	RW12**	3.7	234.0	> 6.1	Below 228.0

\* Silt Interlayer

\*\* Including a 1.5 m thick zone of silty clay lenses from Elevation 231.5 m

The results of grain size distribution testing completed on one sample each of the sandy silt to sand deposit and the silt deposit from the current investigation are shown on Figures B3 and B4 in Appendix B.

The SPT "N"-values measured within the sandy silt to sand deposit range from 8 to 44 blows per 0.3 m of penetration, indicating a loose to dense relative density; and the SPT "N"-values measured within the silt interlayer range from 4 blows to 22 blows per 0.3 m of penetration indicating a very loose to compact relative density.





### 4.3 Groundwater Conditions

The observed water levels in the open boreholes following completion of drilling and the water level measured by Coffey in the standpipe piezometers are summarized as follows:

<b>Culvert Structure</b>	<b>Borehole No.</b>	<b>Ground Surface Elevation (m)</b>	<b>Groundwater Elevation (m)</b>	<b>Date of Measurement</b>	<b>Notes</b>
Culvert Station 29+280	HF1	233.2	230.1	July 15, 2015	Open Borehole
	C1	232.0	230.2	October 31, 2014	Piezometer
			230.1	November 6, 2015	Piezometer
	C3	233.0	231.5	October 31, 2014	Piezometer
			231.5	November 6, 2015	Piezometer
	C5	238.7	-	-	Not Recorded
Culvert Station 10+120	TRW-3	237.8	227.4	June 23, 2015	Open Borehole
	C2	233.3	229.7	October 31, 2014	Piezometer
			229.4	November 6, 2015	Piezometer
	C4	233.7	231.6	October 31, 2014	Piezometer
			231.2	November 6, 2015	Piezometer
	RW12	237.7	231.0	October 14, 2014	Open Borehole

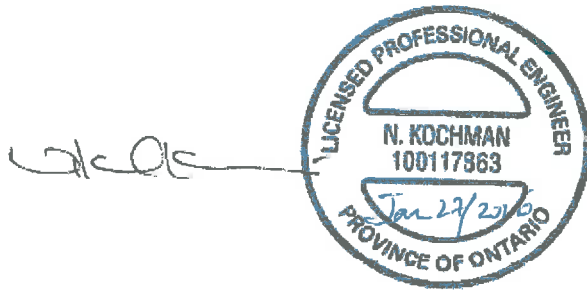
The water levels in the open boreholes are not stabilized. The water levels at the site are expected to fluctuate seasonally in response to changes in precipitation and snow melt, and are expected to be higher during the spring season.



## **5.0 CLOSURE**

This Foundation Investigation Report was prepared by Ms. Caitlyn Cartwright, E.I.T. and Ms. Nikol Kochmanová, P.Eng., and reviewed by Mr. Jorge Costa, P.Eng., a Designated MTO Foundations Contact and Principal of Golder.

### **GOLDER ASSOCIATES LTD.**



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Jorge M.A. Costa, P.Eng.  
Designated MTO Foundations Contact, Principal

CC/NK/LCC/JMAC/sm

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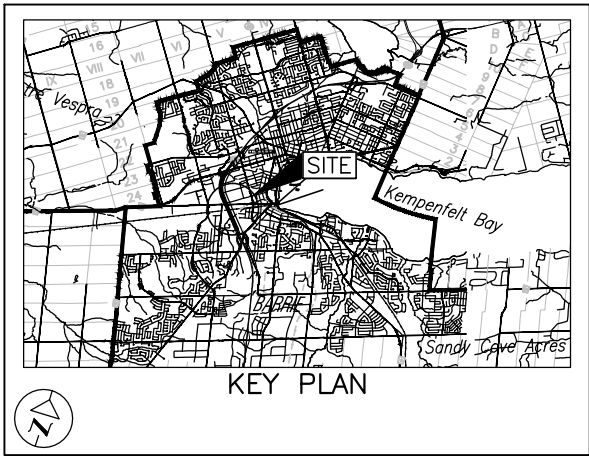
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**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
GWP No. 2159-11-00

HIGHWAY 400  
CULVERT AT STA 29+280  
BOREHOLE LOCATIONS AND SOIL  
STRATA

SHEET



LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation By Others (2014)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- WL in piezometer, measured on OCT 31, 2014
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
HF1	233.2	4914216.0	288583.2
BH C1	232.0	4914237.9	288578.9
BH C3	233.0	4914174.7	288531.9
BH C5	238.7	4914205.6	288547.5

**NOTES**

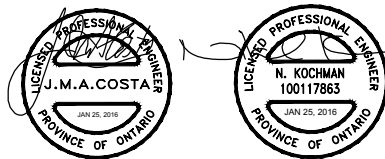
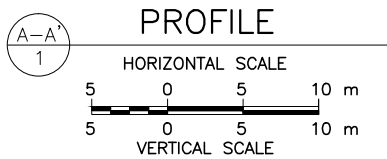
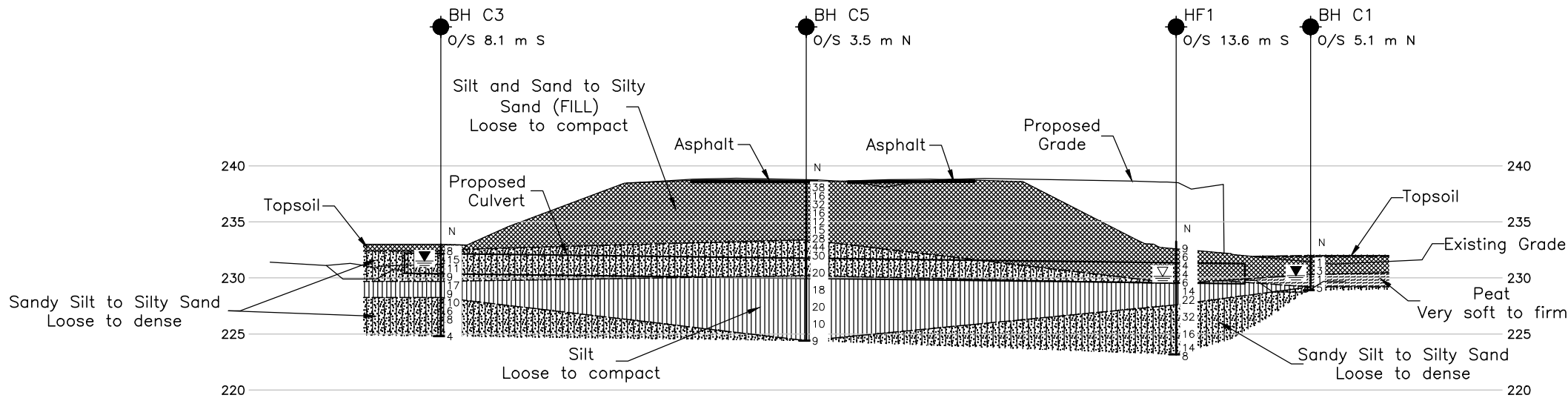
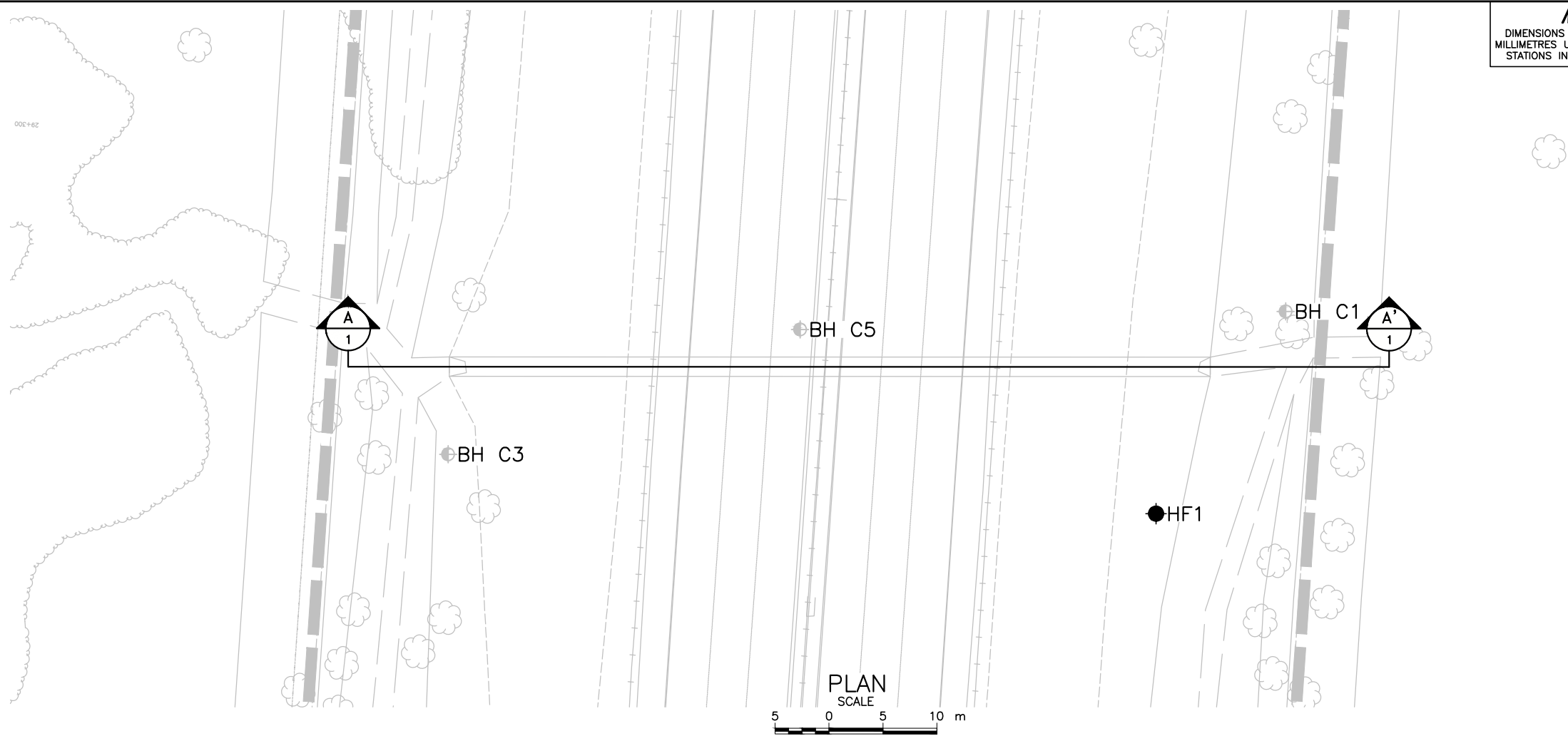
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

**REFERENCE**

Base plans provided in digital format by Morrison Hershfield, drawing file nos. x1124220\_Base.dwg, received Aug. 08, 2015. Proposed culvert profile provided by Morrison Hershfield, drawing file no. NEW-CULVERT-PROFILES\_RAH\_08Jan16.dwg, received Jan. 20, 2016.



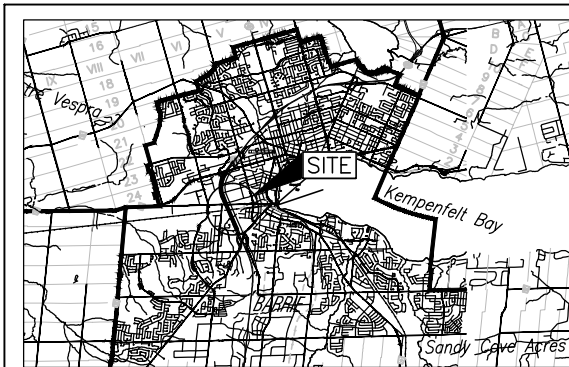
NO.	DATE	BY	REVISION
Geocres No. 31D-634			
HWY. 400	PROJECT NO. 1532543		DIST. CENTRAL
SUBM'D. NLP	CHKD. NLP	DATE: 1/21/2016	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 1

**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
GWP No. 2159-11-00

HIGHWAY 400  
CULVERT AT STA 10+120  
BOREHOLE LOCATIONS AND SOIL  
STRATA

SHEET



KEY PLAN

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation By Others (2014)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- WL in piezometer, measured on OCT 31, 2014
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
TRW-3	237.8	4914663.2	288187.6
BH C2	233.3	4914672.0	288212.1
BH C4	233.7	4914647.2	288140.5
RW12	237.7	4914649.3	288175.8

NOTES

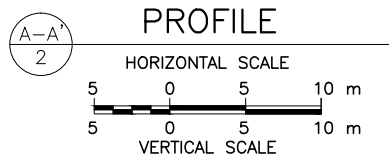
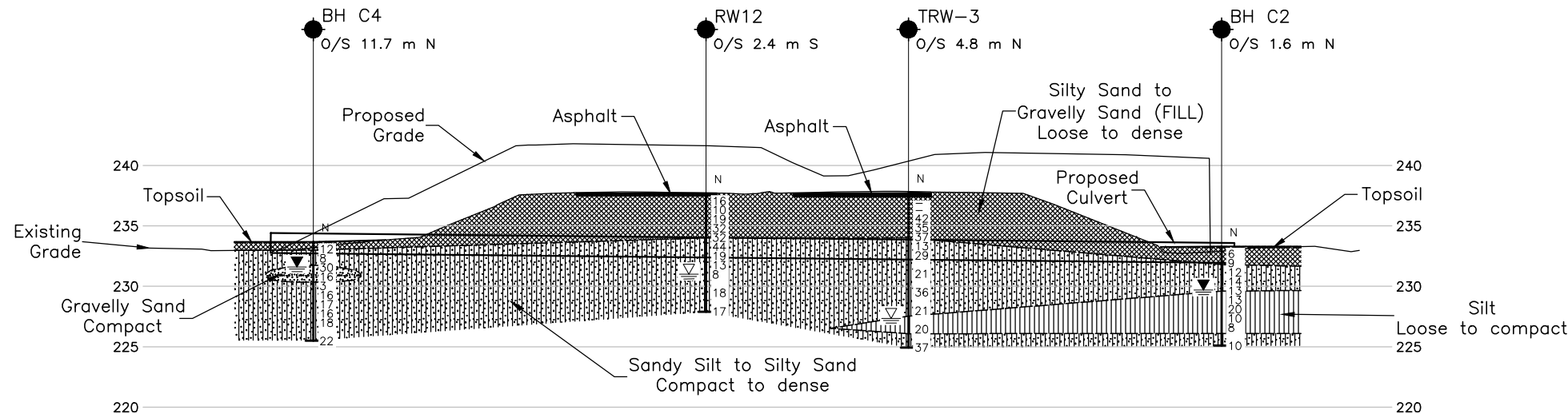
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NO.	DATE	BY	REVISION
1	1/21/2016	JMAC	PROPOSED CULVERT PROFILE

Geocres No. 31D-634

HWY. 400	PROJECT NO. 1532543	DIST. CENTRAL
SUBM'D. NLP	CHKD. NLP	DATE: 1/21/2016
DRAWN: TB	CHKD. NK	APPD. JMAC
		DWG. 2



# **APPENDIX A**

## **Record of Boreholes from Current Investigation**



## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$





## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Dynamic Cone Penetration Resistance; $N_d$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	$C_u, S_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS



w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
$SO_4$	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



PROJECT		1532543				RECORD OF BOREHOLE No HF1				1 OF 1 METRIC							
G.W.P.		2159-11-00		LOCATION		N 4914216.0; E 288583.2				ORIGINATED BY				AK			
DIST		Central		HWY		400		BOREHOLE TYPE		200 mm Diameter Hollow Stem Augers				COMPILED BY		AC	
DATUM		GEODETIC		DATE		July 15, 2015				CHECKED BY				SEMP			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
233.2	GROUND SURFACE																
0.0	Silty sand, trace gravel, trace organic staining, rootlets, some cobbles (FILL)		1	SS	9		233										2 60 35 3
232.6	Loose Dark brown Moist		2	SS	6		232										
0.7	Sand and silt, trace gravel, trace clay, trace organics (FILL)		3	SS	4		231										
	Loose Brown to black Moist		4	SS	4		230										
230.3	Silty sand, trace clay (FILL)	5	SS	6	229												
3.0	Loose Brown Wet	6	SS	14	228												
229.5	SILT, some sand, trace clay Compact Grey Wet	7	SS	22	227												
3.7	- Trace clay seams from 4.3 m to 4.9 m depth.				226												
227.6	SILTY SAND Loose to dense Grey Wet	8	SS	32	225												
5.6		9	SS	16	224												
		10	SS	14													
		11	SS	8													
223.2	END OF BOREHOLE																
10.1	NOTES:  1. Water level at a depth of 3.1 m below ground surface (Elev. 230.1 m) upon completion of drilling.  2. Borehole caved to a depth of 3.1 m (Elev. 230.1 m) upon removal of augers.																

SUD-MTO 001 1532543.GPJ GAL-MISS.GDT 30/11/15 DATA INPUT:

PROJECT 1532543		RECORD OF BOREHOLE No TRW-3				1 OF 1 METRIC											
G.W.P. 2159-11-00		LOCATION N 4914663.2; E 288187.6				ORIGINATED BY AK											
DIST Central HWY 400		BOREHOLE TYPE 200 mm Diameter, Hollow Stem Augers				COMPILED BY AC											
DATUM GEODETIC		DATE June 23, 2015				CHECKED BY SEMP											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
237.8	GROUND SURFACE																
0.0	ASPHALT (350 mm)																
237.4																	
0.4	Sand to silty sand, trace to some gravel (FILL) Dense Brown Moist		1	AS	-		237										11 79 (10)
			2	AS	-												
			3	SS	42		236										
			4	SS	35		235										
			5	SS	37												
	- Silt seams below 3.4 m depth																
234.0							234										
3.7	SAND to SILTY SAND Compact to dense Brown Moist to wet		6	SS	13												
	- Trace organics encountered at 3.8 m depth.		7	SS	29		233										
							232										
			8	SS	21												0 84 (16)
							231										
			9	SS	36		230										
							229										
			10	SS	21		228										
							227										
227.5			11	SS	20												
10.2	SILT, trace sand Compact Grey Wet						226										
226.1																	
11.7	SILTY SAND Dense Grey Wet																
224.9			12	SS	37		225										
12.8	END OF BOREHOLE																
NOTES:																	
1. Water level at a depth of 10.4 m (Elev. 227.4 m) upon completion of drilling.																	
2. Borehole caved to a depth of 7.8 m (Elev. 230.0 m) upon removal of augers.																	

SUD-MTO 001 1532543.GPJ GAL-MISS.GDT 30/11/15 DATA INPUT:

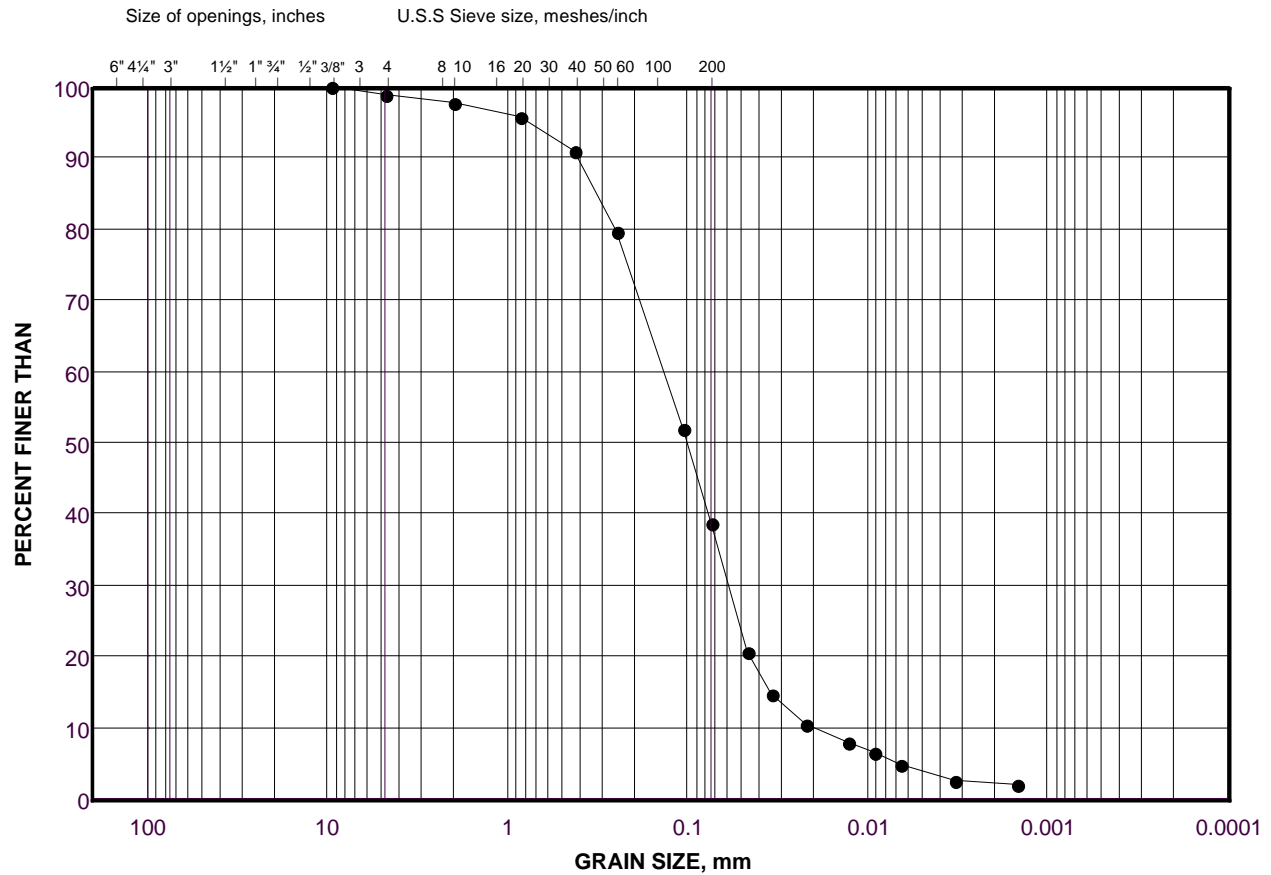


# **APPENDIX B**

## **Geotechnical Laboratory Test Results**

Silt and Sand (Fill)

FIGURE B1



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			
SIZE						FINE GRAINED

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF1	3	231.4

Project Number: 1532543

Checked By: NK

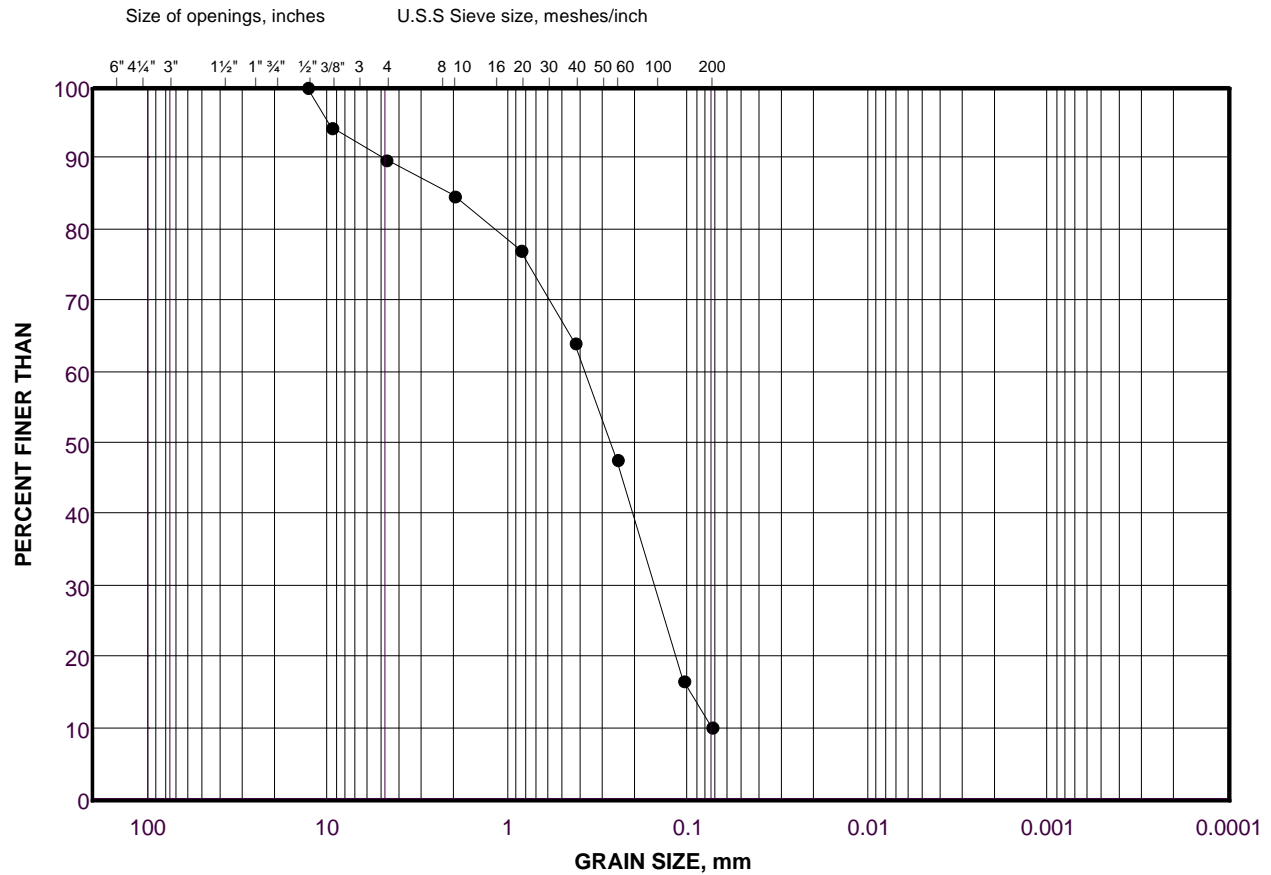
## Golder Associates

Date: 25-Nov-15

# GRAIN SIZE DISTRIBUTION

Sand (Fill)

FIGURE B2



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	TRW-3	2	236.7

Project Number: 1532543

Checked By: NK

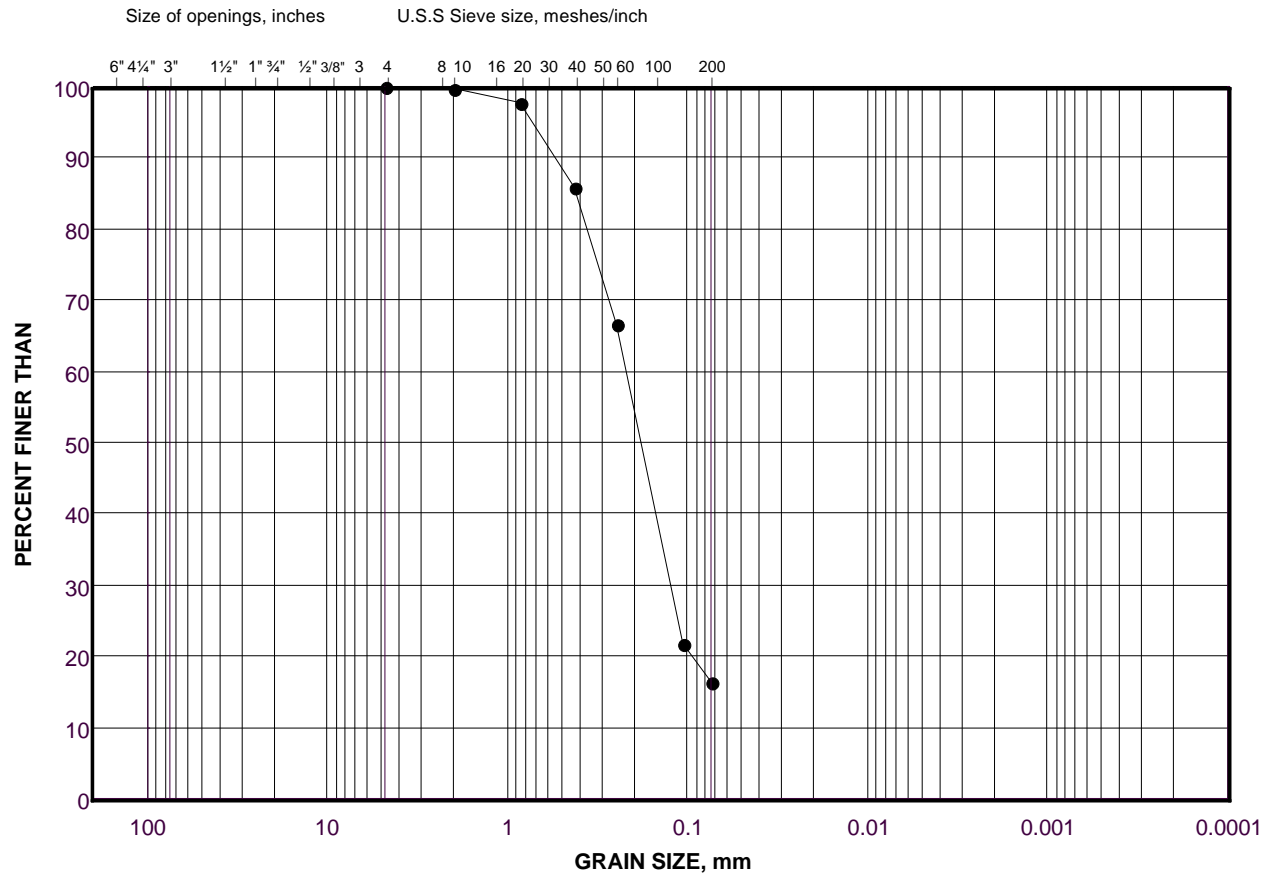
**Golder Associates**

Date: 25-Nov-15

# GRAIN SIZE DISTRIBUTION

Sand

FIGURE B3



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	TRW-3	8	231.3

Project Number: 1532543

Checked By: NK

**Golder Associates**

Date: 25-Nov-15

Silt

Size of openings, inches

U.S.S Sieve size, meshes/inch

PERCENT FINER THAN

GRAIN SIZE, mm

Grain Size (mm)	Percent Finer (%)
0.075	100
0.15	98
0.3	97
0.6	89
1.18	46
2.5	30
4.75	17
7.5	10
12.5	6
20	4
30	2
42.5	1

COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			
SIZE						FINE GRAINED

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF1	7	228.3

Date: 25-Nov-15





# **APPENDIX C**

## **Record of Boreholes from Previous Investigation (GEOCRES No. 31D-589)**

GEOTETO22161AA: Hwy 400/ Tiffin Street

# RECORD OF BOREHOLE No BH C1

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 29+288, 42.4 m R/L C/L (N 4914237.9, E 288578.9) ORIGINATED BY JD  
 DIST            HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP  
 DATUM Geodetic DATE 08/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa) ○ UNCONFINED   + FIELD VANE ● POCKET PENETR.   × LAB VANE		WATER CONTENT (%)  W <sub>P</sub> W   W <sub>L</sub>				
232.0 0.0	GROUND SURFACE						20   40   60   80   100							
	0.1 m TOPSOIL FILL: Silty Sand trace gravel, trace rootlets brown, very loose, moist to wet		1	SS	1									
			2	SS	3									
230.3 1.7	PEAT dark grey to dark brown, very soft to soft, moist		3	SS	1									0 56 38 6 wet spoon
			4	SS	5									
229.2 2.8														
228.9 3.1	SAND AND SILT distant, trace clay grey, firm, wet													
End of Borehole Piezometer installed to 3.1 m. Piezometer water level records : Oct. 31, 2014   1.8 m (El. 230.2 m)														

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 10 5  
(%) STRAIN AT FAILURE

GEOTETO22181AA: Hwy 400/ Tiffin Street

# RECORD OF BOREHOLE No BH C2

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 10+123, 37.8 RI C/L (N 4914872.0, E 288212.1) ORIGINATED BY JD  
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP  
DATUM Geodetic DATE 08/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE					PLASTIC LIMIT w <sub>p</sub>
233.3 0.0	GROUND SURFACE							20 40 60 80 100					
	0.1 m TOPSOIL FILL: Silty Sand trace gravel, trace rootlets brown, loose, moist		1	SS	6		233						
			2	SS	9		232						
231.8 1.5	SILTY SAND grey, compact, moist to wet		3	SS	12		231						0 69 (31) wet spoon
			4	SS	14								
			5	SS	13		230						
228.6 3.7	SILT with occasional silty clay layers, trace sand moist, loose to compact		6	SS	13		229						
			7	SS	20								
			8	SS	10		228						0 1 63 36
			9	SS	8		227						
226.1 7.2	SILTY SAND TO SANDY SILT grey, compact, wet						226						
225.1 8.2	End of Borehole Piezometer installed to 8.2 m. Piezometer water level records : Oct. 31, 2014 3.6 m (El. 229.7 m)		10	SS	10								

GEOTETO22181AA: Hwy 400/ Tiffin Street

# RECORD OF BOREHOLE No BH C3

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 29+274, 34.3 m Lt C/L (N 4914174.7, E 288531.9) ORIGINATED BY LG  
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP  
 DATUM Geodetic DATE 16/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)							
233.0	GROUND SURFACE						20	40	60	80	100				
0.0	0.2 m TOPSOIL		1	SS	8										
232.4	FILL: Sand and Silt														
0.6	trace gravel, trace rootlets														
	brown to grey, loose, moist														
	SANDY SILT TO SILTY SAND		2	SS	15										
	brown to grey, loose to compact, wet														
			3	SS	11										wet spoon
			4	SS	9										0 57 38 5
			5	SS	17										
	silt		6	SS	9										
	trace to some sand, trace clay		7	SS	10										
	brown, compact to loose, wet		8	SS	6										
			9	SS	8										

GEOTETOB22181AA: Hwy 400/ Tiffin Street

# RECORD OF BOREHOLE No BH C4

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 10+150, 33.1 m LL C/L (N 4914647.2, E288140.5) ORIGINATED BY LG  
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP  
 DATUM Geodetic DATE 27/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N <sup>o</sup> VALUES			SHEAR STRENGTH (kPa)							WATER CONTENT (%)		
								UNCONFINED ○ POCKET PENETR.		FIELD VANE + LAB VANE ×					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>
							20 40 60 80 100				10 20 30						
233.7 0.0	GROUND SURFACE																
233.0 0.7	0.1m TOPSOIL FILL: Silty Sand trace organic brown to dark brown, compact, moist		1	SS	12		233										
	SILTY SAND TO SANDY SILT trace organic brown, loose to compact, moist to wet		2	SS	8												
	gravelly sand trace silt		3	SS	30		232							32 59 (9)			
			4	SS	16		231							wet spoon auger grinding due to cobbles 1 45 46 8 0.6 m soil backup			
			5	SS	3		230										
	clayey silt lenses from 3 m to 8.2 m		6	SS	16		229										
			7	SS	17		228										
			8	SS	16		227										
			9	SS	18		226										
225.5 8.2	End of Borehole Piezometer installed to 7.6 m. Piezometer water level records : Oct. 31, 2014 2.1 m (EL 231.6 m)		10	SS	22												

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 10 5  
(%) STRAIN AT FAILURE

GEOTETO22181AA: Hwy 400/ Tiffin Street

# RECORD OF BOREHOLE No BH C5

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 29+288, 2.6 m LI C/L (N 4814205.6, E 288547.5) ORIGINATED BY JD  
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP  
DATUM Geodetic DATE 18/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)						
							20 40 60 80 100	20 40 60 80 100						
							○ UNCONFINED + FIELD VANE	● POCKET PENETR. × LAB VANE						
238.7	GROUND SURFACE													
238.6	150 mm ASPHALT													
0.2	0.5 m gravelly sand		1	SS	38					○				
	FILL: Silty Sand trace organic, trace silty clay lenses brown, dense to compact, moist		2	SS	16					○				
			3	SS	32									
236.1	2.6 silty clay, very stiff		4	SS	16					○				1 22 60 27
	FILL: Silt with occasional silty clay layers, trace sand grey to brown, compact, moist		5	SS	12							○		wet spoon
			6	SS	15					○				
			7	SS	28							○		
233.4	6.3 SILTY SAND trace gravel brown to grey, compact to dense, moist		8	SS	44					○				
			9	SS	30					○				1 76 (23)
	wet		10	SS	20							○		
230.2	8.6 SILT sandy to some sand, trace clay grey, loose to compact, moist													
			11	SS	18							○		1 33 59 7
			12	SS	20							○		
	wet		13	SS	10							○		
	loose													
			14	SS	9							○		
224.4	14.3 End of Borehole													

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15-5  
10 (%) STRAIN AT FAILURE

GEOTETOB22181AA: Hwy 400/ Tiffin Street

# RECORD OF BOREHOLE No BH RW12

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 10+129, 4.5 m Lt C/L (N 4914649.3, E 288175.8) ORIGINATED BY LG  
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP  
DATUM Geodetic DATE 14/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
237.7	GROUND SURFACE													
239.6	220 mm ASPHALT													
0.2	PAVEMENT GRANULAR FILL: 0.3 m Gravelly Sand 0.3 m Sandy, some gravel		1	SS	18		237							
	EMBANKMENT FILL: Silty Sand trace gravel brown, compact to dense, moist		2	SS	10									
			3	SS	19		236							
			4	SS	32		235							
			5	SS	32									
234.0			6	SS	44		234							
3.7	SILTY SAND trace gravel brown to grey, dense to compact moist to wet		7	SS	19		233							
			8	SS	13		232							
			9	SS	8		231							
	loose silty clay lenses		11	SS	18		230							
			12	SS	17		229							
228.0							228							
9.8	End of Borehole Water level @ 6.7 m (not stabilized)* upon completion.													

+<sup>3</sup>, x<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15-5  
10 (%) STRAIN AT FAILURE



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